Mission Simulation Facility: Overview

1. Background

The exploration of remote environments using robotic systems is a very challenging task. The physical robot not only has to withstand the hostile elements of the environment, it also needs to demonstrate high levels of autonomy to accomplish its tasks without continuous human control or intervention.

To accomplish critical science missions, a robot needs to be able to explore an unstructured world and make decisions based on information from on-board sensors. In addition, the robot needs to be capable of adapting its mission to unanticipated events in order to maximize the science return and ensure rover safety.

Research in autonomy for robotic platforms used in remote exploration is therefore critical for mission success. However, this research area faces several challenges when it comes to testing new autonomy concepts:

- Custom simulators usually provide testbeds for individual algorithms without the context of an integrated robotic mission.
- Access to hardware is either very costly or not available at all. Even when hardware is available, time and resource constraints often limit test scenarios to just a few environments. In addition, it can be difficult to control the parameters of the test, making the experiments hard to repeat.

To address these shortcomings the Mission Simulation Facility (MSF) project was initiated in early 2001 to support autonomy research for robotic systems.

2. Research Overview

NASA Ames' Mission Simulation Facility (MSF) was designed to meet a development need that is often encountered by researchers in autonomy: how to carry out meaningful testing of autonomy software without a real-world robotic platform. The Mission Simulation Facility offers a simulated testing environment including robotic vehicle, terrain, sensors, and other features. The initial MSF release targets have been users researching autonomy for Mars rovers; however, the MSF technology solution is applicable to any robotic domain.

The MSF has been developed using a multi-platform, distributed architecture that is a specialization of the Defense Modeling Simulation Office (DMSO) developed High Level

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Architecture (HLA), which allows the simulation to be distributed across multiple machines and laboratories. Multi-platform support allows the MSF to easily integrate with existing simulation software developed on Unix, Linux, and Windows platforms. Among other unique qualities, the MSF has been developed with the goal of distributing the software to outside research groups and universities so that it can be applied to other research applications.

The MSF is a simulation system that represents a diverse collaboration effort. The core technology of the MSF offers a framework for connectivity among modules provided by users or collaborators. Major components of the synthetic world are the terrain surface, environmental conditions, virtual robot, simulated equipment, and graphical display.

The terrain used in MSF to date comes from collaboration with researchers at NASA's Jet Propulsion Laboratory (JPL). The SimScape project is a server-based provider of artificial, realistic, or real-world terrain data including both physical and science characteristics.

Simulated robotic vehicles range from the very simple to the very complex. The MSF provides simple vehicle models based on either kinematics or dynamics. Other vehicle simulations, such as the ROAMS project at JPL can be interfaced with the MSF to provide data related to vehicle subsystems, terrain interactions, and power usage.

The MSF also provides a general interface to instruments and sensors that interact with a virtual site model, which has been developed through collaborative work with JPL.

3. Goals

The goal of the MSF is to develop a simulation framework and suite of simulation tools to support research in autonomy for remote exploration. Such a system will allow developers of autonomy software to test their models in a high-fidelity simulation and evaluate their system's performance against a set of integrated, standardized simulations. There is currently a large gap between autonomy software at the research level and software that is ready for mission insertion. It is our vision that the MSF will bridge this gap by providing researchers with high-fidelity simulations of mission scenarios to test their software in realistic, complex environments.

4. Objective

The MSF is being developed to satisfy the following requirements, which were defined at the outset of the project.

- Provide a software framework for the development of differing levels of autonomy
- Allow easy integration of autonomy modules and tools into the simulation
- Be easily extensible to multiple robotic platforms / environments

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- Allow interchangeability of real hardware with simulated components
- Be distributable to external groups
- Provide varying levels of simulation fidelity
- Provide migration path for autonomy software from research to missions

5. NASA Application

The MSF has teamed with several simulation groups at the Jet Propulsion Laboratory (JPL) (environment, science instruments, and robotic models) that are developing simulations in for use in mission development and testing. These groups provide high fidelity models to the MSF through jointly developed simulations (Rover Analysis, Modeling and Simulation, **ROAMS**) and interface/server (Simulation of Surface Characteristics and Attributes for Planetary Environments, **SimScape**) that will allow users of the MSF to provide NASA project managers with a better sense of the preparedness of those software components for upcoming space missions.

In addition, the MSF team has developed a number of software models in support of the IS milestone, which is a demonstration of key autonomy technologies for robotic exploration missions. The MSF fame work and these specific models give developers of the individual autonomy component the opportunity to perform stand-alone as well as integration testing without requiring access to hardware or other components that may not be ready for integration.

6. Milestones

MSF has been released to Ames internal groups for supporting the IS milestone. This release includes all the basic capabilities, including a Federated Tool Kit (FTK), a library of communication objects (COM) as well as basic and specialized simulation models (rover, power, detector, instrument placement, and probabilistic failure). This version of MSF uses ROAMS as its kinematic/dynamic engine, and Viz for 3-D graphical display of the rover interacting with its environment.

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